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CHEMISTRY
HIGHER LEVEL
PAPER 1

Wednesday 12 May 2010 (afternoon)

1 hour

INSTRUCTIONS TO CANDIDATES

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The periodic table is provided for reference on page 2 of this examination paper.

The Periodic Table

1	2													3	4	5	6	7	0
1 **H** 1.01																			2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01													5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31													13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.71	29 **Cu** 63.55	30 **Zn** 65.37			31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 98.91	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.40			49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.30
55 **Cs** 132.91	56 **Ba** 137.34	57 † **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.21	77 **Ir** 192.22	78 **Pt** 195.09	79 **Au** 196.97	80 **Hg** 200.59			81 **Tl** 204.37	82 **Pb** 207.19	83 **Bi** 208.98	84 **Po** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 ‡ **Ac** (227)																	

Atomic Number

Element

Atomic Mass

†	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 146.92	62 **Sm** 150.35	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.92	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
‡	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (242)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (254)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

1.   What is the approximate molar mass, in $g \ mol^{-1}$, of $MgSO_4 \cdot 7H_2O$?

   A.   120

   B.   130

   C.   138

   D.   246

2.   Which is both an empirical and a molecular formula?

   A. C_5H_{12}

   B. C_5H_{10}

   C. C_4H_8

   D. C_4H_{10}

3. 12 molecules of hydrogen gas, $H_2(g)$, and 5 molecules of oxygen gas, $O_2(g)$, were mixed together under conditions which allowed the reaction to go to completion, according to the following equation.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$
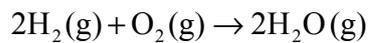
The following diagram represents the mixture of reactants.
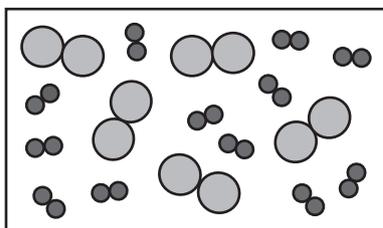
Key:

⬤ Oxygen atom

● Hydrogen atom

Which diagram represents the reaction mixture when the reaction was complete?

A.

B.

C.

D.
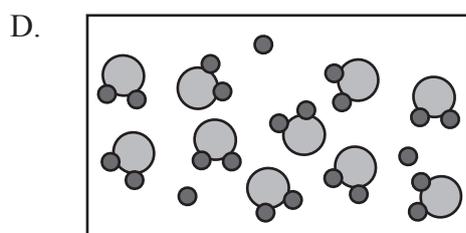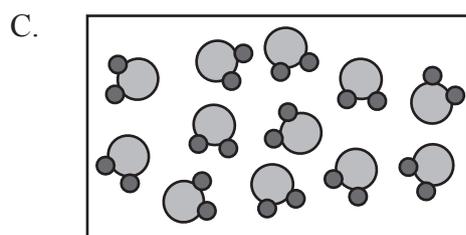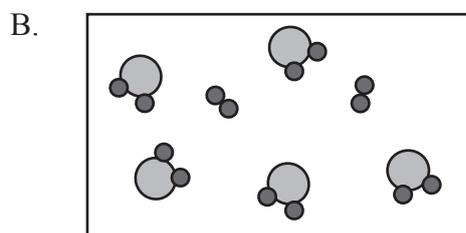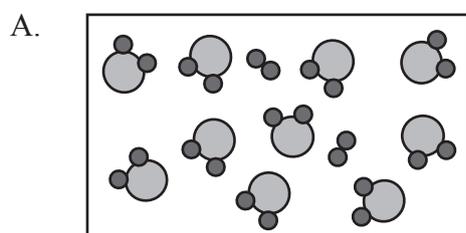
4. Which describes the visible emission spectrum of hydrogen?

  A. A series of lines converging at longer wavelength

  B. A series of regularly spaced lines

  C. A series of lines converging at lower energy

  D. A series of lines converging at higher frequency

5. The graph represents the energy needed to remove nine electrons, one at a time, from an atom of an element. Not all of the electrons have been removed.
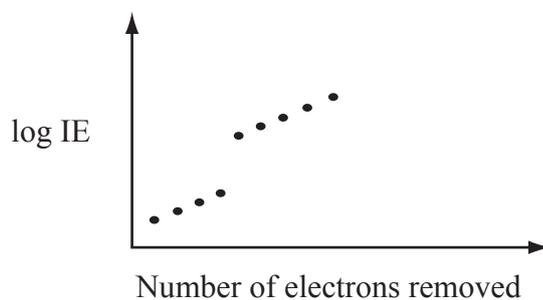
Which element could this be?

  A. C

  B. Si

  C. P

  D. S

6. An ion has the electron configuration $1s^2 \, 2s^2 \, 2p^6 \, 3s^2 \, 3p^6 \, 3d^{10}$. Which ion could it be?

  A. Ni^{2+}

  B. Cu^+

  C. Cu^{2+}

  D. Co^{3+}

Turn over

7. Which statements about the periodic table are correct?

 I. Elements in period 3 have similar chemical properties.

 II. Elements in group 7 show a gradual change in physical properties.

 III. The position of an element in period 3 is related to the number of electrons in the highest occupied energy level.

 A. I and II only

 B. I and III only

 C. II and III only

 D. I, II and III

8. Which statements about period 3 are correct?

 I. The oxides of the elements change from ionic to covalent across period 3.

 II. The oxides of the elements change from basic to acidic across period 3.

 III. First ionization energy of the elements increases linearly across period 3.

 A. I and II only

 B. I and III only

 C. II and III only

 D. I, II and III

9. Which statements are correct for the complex ion $[CuCl_4]^{2-}$?

 I. The oxidation number of Cu in the complex ion is +2.

 II. The coordination number of the copper ion is 4.

 III. Chloride ions are behaving as ligands.

 A. I and II only

 B. I and III only

 C. II and III only

 D. I, II and III

10. Which molecule has the shortest carbon-oxygen bond length?

   A. CH_3COOH

   B. CH_3CH_2OH

   C. CO_2

   D. CO

11. Which pair of compounds is arranged in correct order of relative boiling points?

	Lower Boiling Point	Higher Boiling Point
A.	CH_3OCH_3	CH_3CH_2OH
B.	CH_3CHO	$CH_3CH_2CH_3$
C.	CH_3CH_2OH	CH_3CHO
D.	CH_3COOH	CH_3CH_2OH

12. Which intermolecular forces exist between molecules of carbon monoxide, CO?

   A.   Hydrogen bonds and van der Waals' forces

   B.   Dipole-dipole attractions and van der Waals' forces

   C.   Van der Waals' forces only

   D.   Dipole-dipole attractions only

13. Which statements about σ and π bonds are correct?

      I. σ bonds result from the axial overlap of orbitals.

      II. σ bonds only form from s orbitals.

      III. π bonds result from the sideways overlap of parallel p orbitals.

    A.   I and II only

    B.   I and III only

    C.   II and III only

    D.   I, II and III

14. In which substance does a carbon atom have sp^2 hybridization?

    A.   2-methylbutan-1-ol

    B.   Propyne, CH_3CCH

    C. C_{60} fullerene

    D.   Diamond

15. Which types of reaction are always exothermic?

      I.   Neutralization

      II.   Decomposition

      III. Combustion

    A.   I and II only

    B.   I and III only

    C.   II and III only

    D.   I, II and III

16. Which reaction has an enthalpy change equal to a standard enthalpy change of formation, $\Delta H_f^{\ominus}$?
All reactions occur at 298 K and 1.01×10^5 Pa.

A. $C_4H_8(g) + H_2O(g) \rightarrow C_4H_9OH(l)$

B. $4CO_2(g) + 5H_2O(g) \rightarrow C_4H_9OH(l) + \frac{13}{2}O_2(g)$

C. $4C(s) + 5H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_4H_9OH(l)$

D. $8C(s) + 10H_2(g) + O_2(g) \rightarrow 2C_4H_9OH(l)$

17. Which process has an enthalpy change that represents the lattice enthalpy of sodium chloride?

A. $NaCl(s) \rightarrow Na^+(g) + Cl^-(g)$

B. $NaCl(s) \rightarrow Na(s) + \frac{1}{2}Cl_2(g)$

C. $NaCl(g) \rightarrow Na^+(g) + Cl^-(g)$

D. $NaCl(s) \rightarrow Na(s) + Cl(g)$

18. Which is the correct order of increasing magnitude of lattice enthalpy (lowest first)?

A.   NaCl < KCl < MgS < MgO

B.   MgO < MgS < KCl < NaCl

C.   KCl < NaCl < MgS < MgO

D.   MgO < NaCl < KCl < MgS

19. Which experimental procedure could be used to determine the rate of reaction for the reaction between a solution of cobalt chloride, $CoCl_2(aq)$, and concentrated hydrochloric acid, $HCl(aq)$?

$$Co(H_2O)_6{}^{2+}(aq) \ + \ 4Cl^-(aq) \rightleftharpoons CoCl_4{}^{2-}(aq) + 6H_2O(l)$$
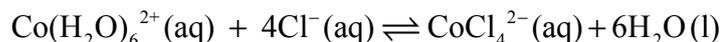
A. Measure the change in pH in a given time

B. Measure the change in mass in a given time

C. Use a colorimeter to measure the change in colour in a given time

D. Measure the change in volume of the solution in a given time

20. Powdered manganese(IV) oxide, $MnO_2(s)$, increases the rate of the decomposition reaction of hydrogen peroxide, $H_2O_2(aq)$. Which statements about MnO_2 are correct?

    I. The rate is independent of the particle size of MnO_2.

    II. MnO_2 provides an alternative reaction pathway for the decomposition with a lower activation energy.

    III. All the MnO_2 is present after the decomposition of the hydrogen peroxide is complete.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

Questions 21 and 22 refer to the following reaction.

Sodium thiosulfate solution, $Na_2S_2O_3(aq)$, and hydrochloric acid, $HCl(aq)$, react spontaneously to produce solid sulfur, $S(s)$, according to the equation below.

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(aq) + H_2O(l)$$
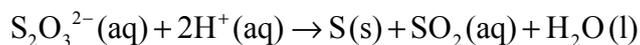
A student experimentally determined the rate expression to be:

$$\text{rate} = k\ [S_2O_3^{2-}(aq)]^2$$

21. Which graph is consistent with this information?

A.

Rate / mol dm^{-3} s^{-1}

$[S_2O_3^{2-}(aq)]$ / mol dm^{-3}

B.

Rate / mol dm^{-3} s^{-1}

$[S_2O_3^{2-}(aq)]$ / mol dm^{-3}

C.

Rate / mol dm^{-3} s^{-1}

$[S_2O_3^{2-}(aq)]$ / mol dm^{-3}

D.

Rate / mol dm^{-3} s^{-1}

$[S_2O_3^{2-}(aq)]$ / mol dm^{-3}
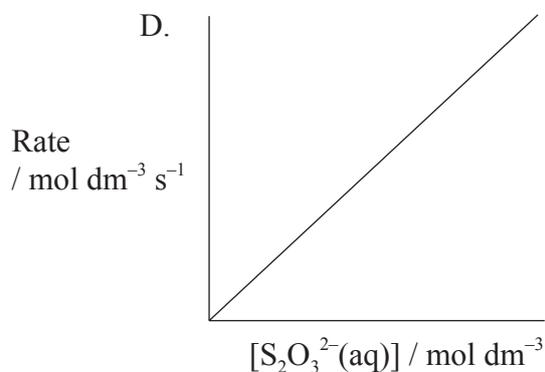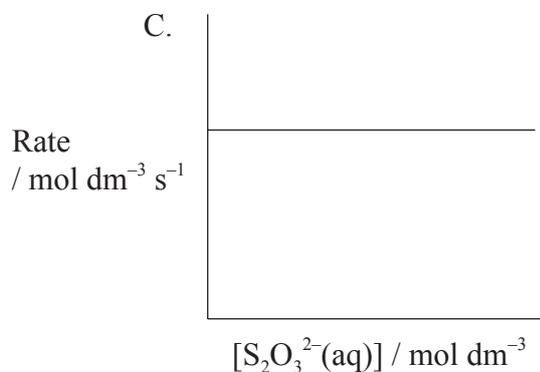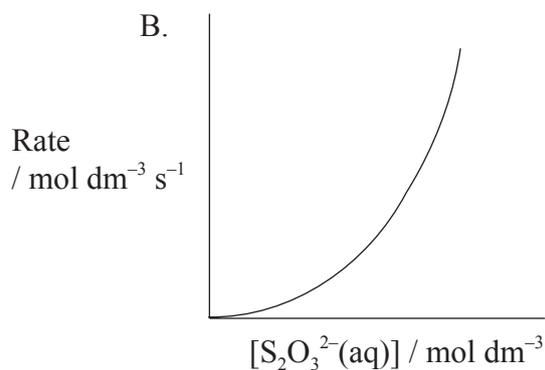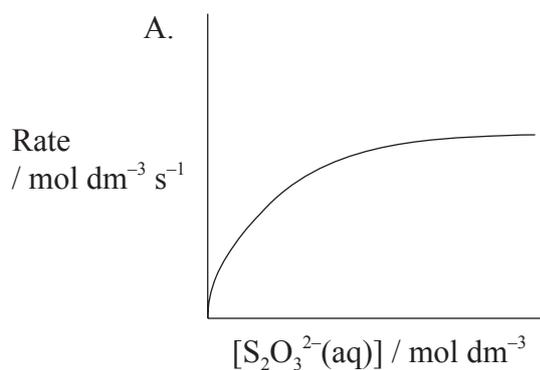
22. Which reaction could be the rate-determining step?

A. $S_2O_3^{2-}(aq) + H^+(aq) \rightarrow S_2O_2(aq) + OH^-(aq)$

B. $S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S_2O_2(aq) + H_2O(l)$

C. $S_2O_3^{2-}(aq) \rightarrow S(s) + SO_3^{2-}(aq)$

D. $2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{4-}(aq)$

23. Which statement is correct for a crystal of iron(II) sulfate in a state of equilibrium with a saturated solution of iron(II) sulfate?
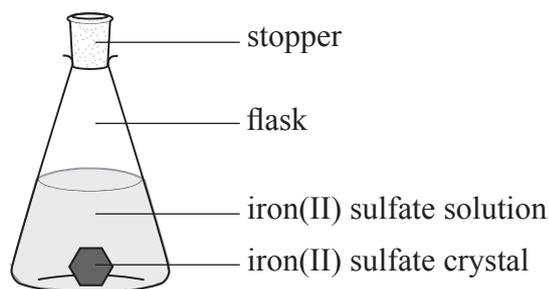
A.   The colour of the solution darkens as the crystal continues to dissolve.

B.   The concentration of the iron(II) sulfate solution increases as the water evaporates.

C.   The shape of the iron(II) sulfate crystal does not change.

D.   The colour of the solution does not change but the shape of the crystal may change.

24. Consider the equilibrium between methanol, $CH_3OH(l)$, and methanol vapour, $CH_3OH(g)$.

$$CH_3OH(l) \rightleftharpoons CH_3OH(g)$$
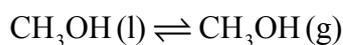
What happens to the position of equilibrium and the value of K_c as the temperature decreases?

	Position of equilibrium	Value of K_c
A.	shifts to the left	decreases
B.	shifts to the left	increases
C.	shifts to the right	decreases
D.	shifts to the right	increases

25. Which statement about acids is correct?

A.   A Brønsted-Lowry acid donates an electron pair.

B.   A Lewis acid donates a proton.

C.   A Brønsted-Lowry acid accepts a proton.

D.   A Lewis acid accepts an electron pair.

26. A student has equal volumes of 1.0 mol dm^{-3} sodium hydroxide and ammonia solutions. Which statement about the solutions is correct?

    A.   Sodium hydroxide has a lower electrical conductivity than ammonia.

    B.   Sodium hydroxide has a higher hydrogen ion concentration than ammonia.

    C.   Sodium hydroxide has a higher pH than ammonia.

    D.   Sodium hydroxide has a higher hydroxide ion concentration than ammonia.

27. What is the K_b expression for the reaction of ethylamine with water?

    A. $K_b = [CH_3CH_2NH_3{}^+][OH^-]$

    B. $K_b = \dfrac{[CH_3CH_2NH_3{}^+][OH^-]}{[CH_3CH_2NH_2]}$

    C. $K_b = \dfrac{[CH_3CH_2NH_3{}^+][H_2O]}{[CH_3CH_2NH_2]}$

    D. $K_b = [CH_3CH_2NH_2][H_2O]$

28. When these 1.0 mol dm^{-3} acidic solutions are arranged in order of increasing strength (weakest first), what is the correct order?

        acid in solution X $K_a = 1.74 \times 10^{-5} \text{ mol dm}^{-3}$ at 298 K
        acid in solution Y $K_a = 1.38 \times 10^{-3} \text{ mol dm}^{-3}$ at 298 K
        acid in solution Z $K_a = 1.78 \times 10^{-5} \text{ mol dm}^{-3}$ at 298 K

    A.   X < Z < Y

    B.   X < Y < Z

    C.   Z < X < Y

    D.   Y < X < Z

29. Consider an acid-base indicator solution.

$$HIn\,(aq) \rightleftharpoons H^+(aq) + In^-(aq)$$
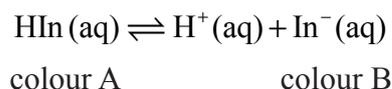
colour A   colour B

What is the effect on this acid-base indicator when sodium hydroxide solution is added to it?

A.   Equilibrium shifts to the right and more of colour B is seen.

B.   Equilibrium shifts to the left and more of colour B is seen.

C.   Equilibrium shifts to the right and more of colour A is seen.

D.   Equilibrium shifts to the left and more of colour A is seen.

30. Consider the following reaction.

$$2FeSO_4(aq) + H_2O_2(aq) + H_2SO_4(aq) \rightarrow Fe_2(SO_4)_3(aq) + 2H_2O\,(l)$$
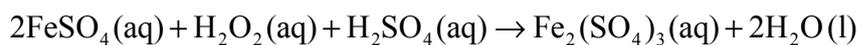
Which species is the oxidizing agent and which is the reducing agent?

	Oxidizing agent	**Reducing agent**
A.	$H_2O_2(aq)$	$H_2SO_4(aq)$
B.	$H_2O_2(aq)$	$FeSO_4(aq)$
C.	$FeSO_4(aq)$	$H_2O_2(aq)$
D.	$H_2SO_4(aq)$	$H_2O_2(aq)$

31. What conditions are necessary to directly measure a standard electrode potential $(E^\ominus)$?

    I.   A half-cell with an electrode in a 1.0 mol dm^{-3} solution of its ions.

    II.   Connection to a standard hydrogen electrode.

    III. A voltmeter between half-cells to measure potential difference.

    A.   I and II only

    B.   I and III only

    C.   II and III only

    D.   I, II and III

32. What condition is necessary for the electroplating of silver, Ag, onto a steel spoon?

    A.   The spoon must be the positive electrode.

    B.   The silver electrode must be the negative electrode.

    C.   The spoon must be the negative electrode.

    D.   The electrolyte must be acidified.

33. Which is the best definition of structural isomers?

    A.   Compounds which have atoms with the same atomic numbers but different mass numbers

    B.   Compounds which have the same general formula but differ by a CH_2 group

    C.   Compounds which have the same empirical formula but different molecular formulas

    D.   Compounds which have the same molecular formula but different arrangements of atoms

34. Which is the correct classification of these alcohols?

	1	2	3
A.	tertiary	secondary	primary
B.	tertiary	primary	secondary
C.	tertiary	tertiary	secondary
D.	secondary	primary	secondary

35. Which substances are possible products of the incomplete combustion of octane?

A. Carbon dioxide and hydrogen gas

B. Carbon monoxide and water vapour

C. Carbon monoxide and hydrogen gas

D. Methane and hydrogen gas

36. What is the IUPAC name of $CH_3CH_2CONH_2$?
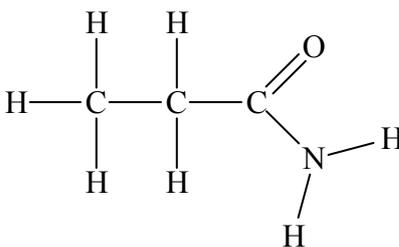
A.   Aminopropanal

B.   Ethanamide

C.   Propylamine

D.   Propanamide

37. What is the main organic product formed from the reaction of CH_3CH_2OH with $CH_3CH_2CH_2COOH$ in the presence of an acid catalyst?

A.   Ethyl butanoate

B.   Butyl ethanoate

C.   Ethyl propanoate

D.   Propyl ethanoate

38. What are some uses of esters?

     I.   Flavouring agents

     II.   Perfumes

     III. Solvents

A.   I and II only

B.   I and III only

C.   II and III only

D.   I, II and III

39. How many isomers can exist for a compound with the molecular formula $C_2H_2Cl_2$?

    A.   1

    B.   2

    C.   3

    D.   4

40. Which experimental procedure is most likely to lead to a large systematic error?

    A.   Determining the concentration of an alkali by titration with a burette

    B.   Measuring the volume of a solution using a volumetric pipette

    C.   Determining the enthalpy change of neutralization in a beaker

    D.   Measuring the volume of a gas produced with a gas syringe